TOXICS IN PUGET SOUND

REVIEW AND ANALYSIS TO SUPPORT TOXIC CONTROLS

APRIL 2006

Scott Redman | Anne Criss
John Dohrmann | Ron Shultz

PUGET SOUND ACTION TEAM
Office of the Governor | State of Washington

P.O. BOX 40900, OLYMPIA, WA 98504-0900 | WWW.PSAT.WA.GOV | 800.54.SOUND

Table of Contents

List of Tables

List of Figures

Toxics in Puget Sound:
Review and Analysis to Support Toxic Controls

1. Introduction

Over the past 150 years, human activities around Puget Sound have introduced a wide array of chemicals that can be poisonous and cause health problems for humans, animals, and plants when they enter the aquatic ecosystem through various pathways. Common practices of handling materials and wastes have evolved with many advances in chemical controls and waste management having occurred over the past 30 years. However, toxic chemicals continue to be released and make their way into the Puget Sound environment, which is already impacted by legacy contamination.

The mission of the Puget Sound Action Team (PSAT) is to protect and restore Puget Sound. Based on prior investigations, PSAT and others have identified toxic chemicals as a key factor affecting the health of Puget Sound.[1] In this document PSAT staff presents evidence that toxic contamination harms the Puget Sound ecosystem and must be addressed by continuing and enhanced control activities. Specifically, we:

- present evidence to demonstrate that toxic contaminants harm and threaten the health of Puget Sound and its biological resources;
- describe sources of toxic chemicals to Puget Sound and the pathways by which contaminants enter and distribute through Puget Sound;
- describe existing programs and initiatives to reduce toxic harms and risks; and
- present recommendations to address key gaps in existing toxics control programs and initiatives..

This document is intended as one piece of input to decision making about the strategies and actions for the collaborative work to conserve and restore Puget Sound under the auspices of PSAT and Governor Gregoire's Puget Sound Initiative. Additional staff work, beyond the scope of this document, to support decision makers might include analysis of the relative priority of recommendations, development of this document's ideas into feasible strategies (i.e., for the 2007-09 biennium or for the 2020 planning horizon), and development of performance measures and corresponding metrics.

2. Evidence of Harm and Risk from Toxic Chemicals in Puget Sound

In 1998, the Puget Sound/Georgia Basin International Task Force established the Puget Sound Toxics Work Group (PSTWG) to identify the toxic chemicals in the shared waters (with British Columbia), evaluate their risk, and propose to the BC/Washington Environmental Cooperative Council and regulatory agencies a strategy to minimize this risk to the environment and economic well-being of our communities. The PSTWG met four times between 1999 and 2002, and contracted with EVS Environmental Consultants for a review of status, trends and effects of toxic contaminants in the Puget Sound environment. The report[2], released in 2003, describes some of the many types of harm caused by toxics that have been documented in the Puget Sound marine ecosystem. Except where otherwise noted, the statements in this section are excerpted from the EVS review; please refer to that document for a more complete presentation of this evidence.

In the sections below we describe harm and risks in nine areas:

- contaminated sediments and impaired communities of sediment-dwelling organisms;

- liver lesions and reproductive impairment in fish from exposure to toxic organic chemicals found in urban bays;
- suppressed immune function in, and other harms to, salmon and marine mammals caused by organochlorine contaminants;
- risks to human health from consumption of contaminated Puget Sound seafood;
- harm and risks from spills of oil and other hazardous materials;
- harm to salmonids and other stream organisms from stormwater contaminants;
- possible effects on viability of marine populations;
- poorly described risks from chemicals used in industry, pharmaceuticals, and personal care products; and
- risks from future releases.

The first six of these sections relate to observed harm and relatively well-characterized risks. The last three sections address additional types of harm that may be occurring or may occur in the future due to the current array of toxic chemicals present in Puget Sound[3] and the potential for future contamination.

2.1 Communities of sediment-dwelling organisms are harmed by toxic chemicals

Toxic harm to communities of invertebrates in the sediment of Puget Sound has long been recognized:

- Observations of harm (community impairment and/or laboratory-measured toxicity) corresponding to levels of contamination in various locations around Puget Sound allowed the delineation of threshold concentrations of effects which provide the basis for many of Washington State's sediment quality standards.

- Ecology has identified 115 sites contaminated sediment in Puget Sound,[4] covering approximately 3,000 acres. Sediments at these sites are contaminated, or demonstrate biological harm to sediment-dwelling organisms, to the degree that sediment clean up is warranted.

- A NOAA-Ecology survey estimated that 5,600 acres of Puget Sound sediments suffer impaired benthic communities, elevated levels of contamination, and observable levels of toxicity in laboratory tests. This type of toxic harm was observed in all areas of Puget Sound except Hood Canal. Contaminants present at harmful levels include: arsenic, copper, lead, mercury, polycyclic aromatic hydrocarbons (PAHs) polychlorinated biphenyls (PCBs), furans, phthalate esters, and DDT.

2.2 Resident organisms from urban locations suffer liver lesions and reproductive impairment from exposures to toxic organic chemicals

English sole are bottom dwelling organisms and spend a majority of their time near sediments to which many contaminants are bound. Therefore, they are a good indicator of toxic harm in particular locations. English sole from urban bays are more contaminated and show greater levels of toxic effects than fish from less urban locations around Puget Sound.

Exposures to PAHs (especially), PCBs, and DDT and its derivatives increase risks of developing several types of liver lesions in English sole from urban areas (e.g., Hylebos waterway in Commencement Bay) of Puget Sound.

Inhibited ovary development and early (precocious) maturation have been observed in English sole from urban areas of Puget Sound and are associated with exposures to PAHs (both effects) and chlorinated hydrocarbon (precocious maturation only). These effects are estimated to reduce production of offspring to 75 percent of the levels achieved in less urban settings of the Sound.

Reproductive development in male and female English sole from Puget Sound's urban bays, especially Elliott Bay, appears to be affected by environmental contaminants. At Elliott Bay and other urban sites, male sole produce vitellogenin, a yolk protein normally only produced in sexually mature females. Further, the reproductive cycle of female sole from Elliott Bay appears disrupted: they enter vitellogenesis earlier in the season, their eggs mature and they spawn later in the season, and they appear to mature at a smaller size and younger age compared to fish from reference sites in Puget Sound.[5] These effects are all symptoms of hormone disruption, which can be caused by exposure to environmental contaminants that mimic or disturb hormone function.

2.3 Organochlorine contaminants suppress immune function of Puget Sound salmon and marine mammals and may cause other harms to Puget Sound organisms

Juvenile salmon from the contaminated Duwamish River estuary, which enters into Elliott Bay, are more susceptible to disease (including lethal infections) than fish from clean areas and remain susceptible for two months after removal from the contaminant source. Elevated contaminants in fish from the contaminated area included PCBs, DDT, and metabolites of PAHs.

Levels of PCBs in the blubber of Puget Sound harbor seals suggest that these animals might suffer from impaired immune function: observed concentrations are above an effects threshold of 17 mg/kg of lipid.

Schmidt and Johnson's (2001) review of "Toxics in the Puget Sound Food Web"[6] begins with an account of the death of J-18 (Everett) a member of the community of orcas that resides part of the year in Puget Sound. Their synopsis suggests that J-18's "death was most likely caused by a common infection." Their explanation of his death notes that J-18 carried high levels of PCBs in his blubber, appeared to have lost fat reserves, possibly as a result of a limited supply of salmon, and may have suffered from a weakened immune system as a result of the PCBs mobilized into his blood supply as he lost fat reserves.

Organochlorine contaminants such as PCBs and organochlorine pesticides may also cause other effects in fish, birds, and mammals, including cancer; impaired development, growth, and reproduction; and altered behavior. For example, concentrations of PCBs in pigeon guillemot eggs collected from Elliott Bay were higher than observed in eggs collected at a rural Puget Sound location and were above levels known to affect hatchability.[7] As of the 1990s, PCBs and chlorinated dioxins and furans have been detected in eggs of great blue herons (and cormorants) in the urban parts of B.C.'s Georgia Basin at concentrations that are toxic to embryos.[8]

2.4 Harm and risks from spills of oil and other hazardous materials

Between 1993 and 2003, more than 418,500 gallons of oil were spilled in Puget Sound.[9]
Oil contamination can "kill marine organisms, reduce their fitness through sublethal effects, and disrupt the structure and function of marine communities and ecosystems."[11] The biological effects of oil contamination can be acute or chronic. Acute exposures are the immediate short-term effects of a single exposure, as from a significant spill. Chronic exposures are ongoing and occur through point sources, leaking pipelines, nonpoint runoff from land based facilities or urban runoff.[12]

Birds and marine mammals with fur are highly vulnerable to harm from spilled oil; The Exxon Valdez spill killed approximately 250,000 birds.[13] Very small amounts of oil can kill birds; oil accumulates in their feathers and the birds die from hypothermia, starvation and drowning. [14] Bird eggs and larval stages of fish are particularly sensitive to toxicity. Mollusks, which do not easily break down petroleum hydrocarbons can accumulate high concentrations of contaminants[16] and can, therefore, be vulnerable to harm from oil spills.

Ecosystem and synergistic effects of spilled oil are not as well understood. Examples from other areas demonstrate, however, that there can be a rippling effect through the ecosystem, when a specific predator or prey population is decimated.

2.5 Harm and risks to salmonids and stream health from current use pesticides, copper, and other stormwater contaminants

Contaminants in stormwater runoff from urban areas can harm salmonids and may harm other aspects of stream health. [17] Laboratory tests show that Chinook parr have reduced response to predation cues when they are exposed to pesticides such as diazinon and carbaryl. Copper has similar effects on olfactory systems. Both of these types of stormwater contaminants may contribute to pre-spawn mortality of coho salmon observed in 20 to 90 percent to urban streams in the Puget Sound basin.

2.6 Toxic threats to humans

Contaminants in fish and shellfish threaten the health of people who eat seafood from Puget Sound. PCBs, mercury, and DDT are found in Puget Sound fish and shellfish at levels of potential concern to human health. State and local advisories are already in place for many Puget Sound waterways including: Dyes Inlet, Eagle Harbor, Manchester State Park, Sinclair Inlet, Indian Island (north end), Duwamish River, King County shorelines except Vashon and Maury islands, Commencement Bay, and Budd Inlet. These advisories, based on health consultations and toxicologists' assessments, include conclusions and recommendations, such as the following from a recent Department of Health (DOH) update to the advisory for the lower Duwamish Waterway:

> "Eating Duwamish resident fish, crabs, and shellfish may be hazardous to your health; do not eat any resident fish (e.g., English sole, starry flounder, perch, etc.), shellfish or crab from the Duwamish River."

DOH has assessed potential health impacts to humans who eat rockfish, English sole, and Chinook and coho salmon from Puget Sound and is developing comprehensive advice to help people understand how to adjust their consumption patterns to achieve a balance between the benefits and risks of consuming fish from Puget Sound.[18]

Illness, disability, premature death, and the threat of these harms can lead to social and economic problems in the region. Social problems might include cultural disruptions in some segments of society, especially native Americans, due to loss of opportunities to harvest and consume seafood and added burdens on health care and educational systems. Toxic harm might also lead to loss of economic productivity due to worker disability and expenditures on environmental clean up and health care. The uneven geographic distribution of toxic threats and harm can lead to a concentration of economic and social burdens within some neighborhoods and segments of society that live and work in these neighborhoods.

2.7 Possible reduced viability of populations of marine organisms

The ecosystem harms discussed above in sections 2.1 to 2.5 may act together and with other factors (e.g., habitat destruction) to limit the viability of populations of marine organisms and salmonids. Toxic harm may have been a factor in the decline of some populations (e.g., Puget Sound Chinook salmon, southern resident orcas) and may limit species recovery for these and other species. Toxic harms might affect population viability through effects on a variety of ecological and biological functions. For example, we suggest that:

- Communities of sediment-dwelling invertebrates impaired by toxic contamination may limit the availability of food for predators such as flatfish, salmon, forage fish, other marine fish, mammals, and birds. This might occur due to reduced biomass of sediment dwellers, changes in community composition away from preferred food items, and/or limited seasonal availability of food as the community of benthic invertebrates becomes dominated by pollution tolerant species.

- The decreased level of productivity of English sole in Puget Sound urban bays may threaten the viability of flatfish populations in these areas. Degraded flatfish populations in Puget Sound urban bays may, in turn, reduce the supply of food for Puget Sound fish and mammals that prey on flat fish in urban areas. While the foraging range of many predators may extend beyond the scale of the affected urban bay, the limited food resource may affect the viability of predators whose habitat needs most closely overlap with the types of habitats that occur in Puget Sound's urban bays.

- The immune suppression, reproductive, developmental, and neurological effects from organochlorine contaminants discussed above may threaten the viability of populations of high-level predators in the Puget Sound food web, including orcas, harbor seals, Chinook salmon, rockfish, and osprey and other fish-eating birds. Reproductive and developmental effects may limit the reproductive capacity of predator populations. Immune suppression and developmental and neurological effects may reduce survival of individuals (e.g., by increased mortality due to diseases, reduced success in foraging and migration, or reduced ability to avoid predators) and thereby reduce the viability of populations.

2.8 Risks and harms from chemicals used in industry, pharmaceuticals, and personal care products

PBDEs, phthalates, and other chemicals used in industry

Polybrominated diphenyl ethers (PBDEs) are used as flame retardants in various products including furniture foam, upholstery, plastics, and electronics. Three formulations of PBDEs are used in consumer products: penta-, octa-, and deca-BDE.[19] Concern about PBDEs and their effect on the environment and human health is relatively recent, beginning with studies in 1998 in Sweden showing rising levels of PBDEs in human breast milk. Subsequent research and monitoring are providing growing evidence that PBDEs persist in the environment and accumulate in living organisms. Traces of the chemicals have been found in aquatic birds and mammals, fish, and in human blood and breast milk in many locations throughout the world including the Puget Sound region.[20] Research results indicate that PBDEs may cause liver toxicity, thyroid toxicity, and neurodevelopmental toxicity[21].

Phthalate esters (or phthalates) are organic chemicals used to soften plastics and as solvents in household, cosmetic and industrial products. Household and cosmetic products that contain phthalates include soap, shampoo, deodorants, hair conditioners, hand lotions, plastic clothing such as raincoats, vinyl flooring, adhesives and detergents. Phthalates are also used in food packaging, garden hoses, medical equipment, and children's toys. In animal studies, high doses of three phthalate esters (DEHP, DBP, and BzBP) during the fetal period have produced lowered testosterone levels, testicular atrophy and other abnormalities.[22] Phthalate esters have been detected in the Duwamish River sediments and fish and crab tissue at levels triggering sediment cleanup activities.[23]

A 2002 review by Canadian scientists[24] discusses a suite of "minimally regulated chemicals" that have been recently detected in the global environment and that may threaten marine mammal health, but that have not yet been extensively studied in Puget Sound or the Georgia Basin. These chemicals include: polychlorinated paraffins, perfluorooctane sulfonate (PFOS), polychlorinated naphthalenes, alkylphenol ethoxylates, and polychlorinated terphenyls. These chemicals are used in a variety of industrial and commercial applications (e.g., flame retardants, plasticizers, textiles, insulation, paints) and occur in some consumer products. Bisphenol A, which is used in the manufacture of polycarbonate plastics may also be an environmental contaminant of concern in the Puget Sound basin.

Pharmaceuticals and personal care products

Consumers purchase 5 billion nonprescription medicines each year and 40 percent of the US population consumes at least one nonprescription drug in any given 48-hour period.[25] People excrete a portion of medicinal drugs that they take. Up to 90 percent of an oral drug can be excreted in human waste.[26] Household disposal of pharmaceuticals may also be a prominent pathway for these contaminants to enter both marine and freshwater environments.[27]

The ecosystem and human health risks from exposure to most pharmaceuticals in the marine environment are not well understood. Pharmaceuticals can be extremely bioreactive. They generally do not bioaccumulate, but the continual supply of these compounds into the environment from a variety of sources leads to long-term exposures. Some pharmaceuticals are hormone disrupting chemicals, such as ethylynlestradiol, the synthetic estrogen found in birth control pills. Hormone disrupting chemicals alter the normal function of the endocrine system common to all vertebrates by changing the natural production, release, transport, metabolism, action, or elimination of hormones.

Personal care products used daily by millions of Puget Sound residents also contain an array of chemicals, including phthalates (discussed above), triclosan (an antimicrobial), and synthetic musks. While more work is needed to determine the individual and combined effects of these chemicals on marine organisms, research has already shown that these contaminants are present in the Puget Sound environment.[28] They may be one of the causes of hormone disruption observed in organisms from Puget Sound and other marine environments, e.g., as recently reported for marine waters near sewage outfalls in Southern California, where the presence of residues from sunscreens in waters was linked with changes in fish gender.[29]

2.9 Future risks

Increased loading of chemicals currently in use. Present-day loadings of toxic contaminants from a variety of sources combine with historic loads to create the patterns of contamination and continued impacts that we observe today. Loadings from some sources may grow in future years as a result of increases in: the population of the Puget Sound basin; the numbers of vehicles in the basin; the amount of fossil fuel combustion in the basin to provide electricity, heat, and to power motor vehicles. For example, as the population in the Puget Sound region increases the quantity of pharmaceuticals released to sewage systems will also increase. Projected future loadings are difficult to estimate, but percentage increases commensurate with population growth might provide our best projections in the absence of difficult-to-predict technological advances (e.g., cleaner burning engines, less harmful pesticides) and societal shifts (e.g., improved methods of disposing of unused pharmaceuticals, decreased vehicle miles traveled as traffic congestion worsens).

New chemicals. According to a recent US Government Accountability Office report, [30] over 700 new chemicals are introduced into commerce every year (e.g., as flame retardants, pesticides, additives in the manufacture of plastics, pharmaceuticals) and current practices do not adequately assess chemicals' risks before they enter commerce. The use and intended or unintended release of these chemicals to the environment may pose additional toxic risks to the Puget Sound ecosystem.

3. Chemicals of concern, sources of their release to and mechanisms of distribution in the Puget Sound marine ecosystem.

3.1 Chemicals of concern

The section above introduced a number of chemicals that cause or threaten harm in Puget Sound due to their toxic effects. Chemicals of concern in Puget Sound include:

Metals (and organometals)	Organic compounds
Arsenic	Polychlorinated biphenyls (PCBs)
Cadmium	Polycyclic aromatic hydrocarbons (PAHs)
Copper	Pesticides
Lead	Dioxins and furans
Mercury	Phthalate esters
Tributyl tin	Polybrominated diphenyl ethers (PBDEs)
	Hormone disrupting chemicals – including bisphenol A, nonylphenol, 17b-estradiol, and ethynylestradiol

This list follows the parameters evaluated for the Puget Sound Toxics Work Group by EVS Consultants[31] with the addition of PBDEs and hormone disrupting chemicals as parameters that have received attention in the past few years.[32,33] The potential toxic effects of these chemicals are summarized in Table 1.

Additional study might lead to expansion of this list to include some of the "minimally regulated chemicals" potentially affecting the Puget Sound Georgia Basin food web and/or persistent, bioaccumulative, and toxic (PBT) chemicals.

3.2 Sources and pathways of distribution and accumulation

The toxic contaminants that harm and threaten Puget Sound include chemicals purposefully synthesized for use in industry, in commerce, or by individuals; byproducts of manufacturing or the combustion of fuel; and elements and compounds that occur naturally but may become concentrated in the environment due to human uses or other activities. Release of these chemicals to the environment can occur through designed and controlled human actions (e.g., application of pesticides; discharge of wastes through outfall pipes, and smokestacks) or as unintended consequences of human activities (e.g., spills; leaching from landfills; deterioration and wear of roof, pavement, and tire materials). Table 2 identifies the contaminant sources and means of environmental release for the toxic chemicals introduced above.

Toxic chemicals that have been released to the environment can be delivered to, distribute through, and accumulate in the Puget Sound marine ecosystem through a variety of mechanisms. Delivery mechanisms (see Figure 1) include:

- discharge of wastewater and stormwater through outfalls,
- nonpoint runoff and groundwater discharge to surface waters,
- spills,
- atmospheric deposition,
- import of contaminants through biological migrations and from the Pacific Ocean.

Delivery by these mechanisms can be direct to Puget Sound's marine waters or through rivers and streams. Atmospheric deposition, biological import, direct release to the land surface (e.g., pesticides, spills to land, abraded tires) contribute contaminants delivered to Puget Sound or freshwater systems via stormwater outfalls, nonpoint runoff, and groundwater discharge.

The amount of a contaminant in Puget Sound's water, biologically active bottom sediments, and biological organisms (depicted by oval on the right side of Figure 1) reflects the amount and rate of contaminant delivery and removal over time. The toxics control efforts discussed in Sections 4 and 5 attempt to decrease the rate of delivery (e.g., by limits on discharges) or increase the rate of removal (i.e., by clean up).

The distribution of a contaminant among water, sediment, and organisms depends on the characteristics of the contaminant; the forces the move water and sediment through Puget Sound; and the food webs that transfer energy, nutrients, and contaminants within the ecosystem. Many contaminants of concern in Puget Sound tend to attach to sediments and/or lipids and, therefore, accumulate in sediments and biological tissues and become especially concentrated in predators. Some contaminant uptake by organisms will occur through contact with contaminants in sediment (i.e., via sediment-based food webs) whereas some uptake may bypass the sediments with accumulation directly from water and suspended sediments to marine organisms (i.e., via water column food webs). Connections between the sediment and water column food webs are numerous and can (1) deliver sediment contaminants to predators up in the water column (e.g., by broadcast of eggs and juveniles of benthic fish into the water column) and (2) lead to accumulation of contaminants from the water column in the bottom sediments (e.g., by settling of algae and fecal material to sediments).

General pathways of biological uptake and concentration of contaminants follow the numerous predator-prey relationships in Puget Sound food webs (e.g., Figure 2). The water column food web depicted in Figure 2 illustrates how energy and contaminants from phytoplankton might make their way to herring and then to marine birds or orcas. A sediment-based food web would include other intermediate species but would also deliver energy and contaminants to orcas and other top predators.

4. Existing toxic control efforts and their institutional arrangements

Efforts to control toxic contamination in the Puget Sound region can be divided into categories that describe the strategic approaches that are being or could be implemented. Efforts within each of six strategic approaches are discussed below. A final section (4.7) discusses how these strategies address contaminant delivery to and removal from Puget Sound.

4.1 Clean up contaminated sites

Washington State Department of Ecology (Ecology) and U.S. Environmental Protection Agency (EPA) oversee cleanups of contaminated sites under authority of state Model Toxics Control Act (MTCA), the federal Resource Conservation and Recovery Act (RCRA), and Superfund law. Washington State Department of Natural Resources (DNR) engages in cleanup that may affect state owned lands. As part of its effort DNR is working with partners to focus some efforts on clean up of wood wastes (e.g., in areas of historic log storage), which can generate and release toxic chemicals to Puget Sound sediments and waters. Ports and local governments engage in cleanups in their jurisdiction. Private parties can undertake voluntary cleanups with or without Ecology oversight.

4.2 Reduce the use and generation of toxic chemicals

EPA oversees programs that institute chemical use restrictions under the authority of statutes such as the Toxic Substance Control Act (TSCA) and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Industries have also implemented voluntary phase-outs of some classes of chemicals (e.g., see discussion of penta- and octa-BDE below).

Ecology, local wastewater utilities, and non-governmental organizations provide technical and engineering assistance that can advise industries about how they might shift manufacturing processes to reduce use of toxics in feedstocks and products.

Local clean air agencies and Ecology provide technical and financial assistance for owners and operators of bus fleets to help retrofit diesel engines.

Ecology leads an effort to phase out persistent, bioaccumulative, and toxic (PBT) chemicals through the development of chemical action plans (CAPs). Ecology has recently finalized a PBT rule that describes how this effort will be pursued under Ecology's leadership. CAPs have been developed for mercury and PBDEs and describe approaches that will be used to reduce the use of these chemicals (e.g., phase out of mercury thermometers; ban the use of some types of PBDEs) and improve the handling and disposal of materials containing these chemicals (e.g., education about mercury, improved management of mercury-containing wastes in dental offices).

Ecology has embarked on a new initiative to emphasize and coordinate efforts to prevent toxic contamination by reducing the use and generation of toxics (e.g., through expanded diesel soot control programs), promoting the substitution of products containing toxic chemicals with safer alternatives, and assisting businesses to find and implement ways reduce the creation of toxic substances. This initiative builds upon earlier efforts by Ecology's solid and hazardous waste programs to shift materials use and management to a new paradigm, i.e., beyond waste.

4.3 Reduce the release of toxic chemicals to the environment

Ecology implements programs to permit discharges of wastewater and stormwater from industrial facilities, wastewater from sewage treatment plants, combined sewer overflows, and stormwater from municipal and Washington State Department of Transportation (WSDOT) stormwater facilities and from construction sites. EPA permits discharges from federal facilities. In recent years, Ecology has developed agreements with cruise ship operators to restrict the discharge of wastewaters from those vessels to certain locations and situations. Discharge permits can include specific limitations on the discharge of toxic contaminants. Permit conditions should reflect permittees' implementation of all known, available, and reasonable treatment technologies (AKART). Permits are issued for 5-year periods at which time they can be renewed or administratively extended. For discharges that affect water bodies with beneficial uses impaired by toxic chemicals, permit conditions are adjusted as needed to improve or protect water or sediment quality (e.g., as determined through a study of total maximum daily loads (TMDLs) or as a source control requirement for contaminated sediment site management).

Local wastewater utilities collect and treat, or provide for the treatment of, the wastewater they collect from their customers. They apply for permits to discharge to discharge treated wastewater and design and operate their collection systems, treatment plants, and outfalls to meet conditions specified in those permits. Some of these utilities also contribute to toxics control by industrial pre-treatment programs (to limit the release of toxics that might upset the operation of treatment plants) and (planning for) reclamation of wastewater.

Local stormwater programs are a key element of PSAT's efforts to reduce harm from stormwater in the Puget Sound basin, including harm from toxic chemicals. Through these programs local governments plan and oversee the operation and maintenance of stormwater management facilities, educate residents about opportunities to keep pollutants out of stormwater, and monitor the effects of stormwater on aquatic systems and the effectiveness of their control efforts.

Ecology administers a program to distribute federal and state funds for water pollution control (i.e., from federal Clean Water Act Section 319 nonpoint pollution control funds, the state Centennial Clean Water fund, and the state revolving loan fund). These funds support water pollution control efforts by local governments, including wastewater and stormwater utilities. A portion of the Section 319 funding is made available to various agencies of state government to implement activities recommended in the state's nonpoint pollution control plan.

Local health districts, Washington State Department of Health (DOH), and Ecology have programs to oversee the management of on-site sewage systems. These programs can contribute to toxics control by educating owners of onsite systems about ways to limit the introduction of toxic chemicals to their systems to protect system operation and the quality of ground- and surface waters.

Ecology and local Clean Air Agencies have primary responsibilities for permitting sources of air emissions and administering motor vehicle emission control programs. Ambient standards have not been established for many air toxics and few permits specify emission limits for toxic air pollutants.

Ecology, local wastewater utilities, clean air agencies, and NGOs provide technical and engineering assistance that can help industrial dischargers reduce the release of contaminants by providing advice about opportunities for improved manufacturing and waste management processes.

Washington State Department of Agriculture (WSDA) ensures agricultural sector compliance with federal pesticide use restrictions and oversees a program to collect waste pesticides for disposal. Conservation districts and WSU Cooperative Extension provide information and education that can help reduce the release of pesticides to the environment during their use, storage, and disposal.

EPA, U.S. Army Corps of Engineers (ACOE), Ecology, and DNR direct the disposal of dredged materials based on their potential to cause toxic harm the Puget Sound ecosystem. Dredged material management sets limits on the re-introduction of contaminants to Puget Sound through in-water disposal of dredge materials and contributes to the removal of toxic contaminants from Puget Sound when dredged materials are disposed in upland facilities.

Control of toxics released from industrial facilities is also achieved by technical and engineering assistance discussed in Section 4.2.

4.4 Improve spill prevention and response

Ecology and the U.S. Coast Guard develop and oversee programs to improve spill prevention, preparedness, and response by facilities that handle oil and by vessels on Puget Sound. Ecology regulates and oversees oil handling facilities and vessels to prevent and prepare responses for spills. Ecology and the U.S. Coast Guard direct and oversee spill response and cleanup.

4.5 Educate residents and business people to change behaviors to reduce toxic contamination

A number of government agencies and NGOs work to educate and provide information and advice for homeowners, businesses, farmers, boaters, and others. Washington SeaGrant Program and Washington State Parks and Recreation Commission (State Parks) educate boaters and marina operators to prevent and improve responses to spills. Conservation Commission and WSDA educate farmers and other agricultural interests regarding best management practices for pesticide use, handling, and disposal. Local governments and utilities educate citizens and customers regarding solid and hazardous waste disposal, and their contributions of contaminants to wastewater and stormwater. DOH and local health jurisdictions issue restrictions and advice related to the consumption of fish and shellfish from Puget

Sound. Data from WDFW monitoring and clean up program assessments usually provide the data to support health assessments.

A variety of NGOs, including those focused on Puget Sound, other environmental, and public health issues, contribute to toxics control through education efforts. For example, a coalition of non-governmental organizations has developed an initiative to move Washington toward a “toxic-free legacy.” The platform of this coalition, headed by six groups including People for Puget Sound, is to phase out existing sources, clean up historical sources, prevent new sources, and promote alternatives to persistent toxic chemicals.

PSAT facilitates public involvement and education regarding toxics control in the Puget Sound region through contracts to local government and utilities and to NGOs.

4.6 Study toxics in Puget Sound and adapt control programs and efforts

Numerous scientists and science coordination programs contribute to efforts to study toxics and ensure that scientific information is available to advise the adaptation of control programs. A few examples are highlighted here.

The Puget Sound Assessment and Monitoring Program (PSAMP) studies the status of and trends in the condition of the Puget Sound marine ecosystem and various stressors on this system, including toxic contaminants. As part of this program:

- Ecology characterizes the distribution and effects of toxic contaminants in Puget Sound sediments.
- Washington State Department of Fish and Wildlife (WDFW) characterizes the exposure of Puget Sound fish to toxic contaminants and collaborates with scientists at the Northwest Fisheries Science Center to study the effects of toxic contaminants on Puget Sound fish.
- US Fish and Wildlife Service (in collaboration with the U.S. Geological Survey) investigates the effects of contaminants on birds and river otters.

Studies of contaminants in harbor seals were historically conducted through PSAMP but are now supported only by occasional grants.

The long-term monitoring information provided by PSAMP supports evaluation of the cumulative effect of toxics control programs. Other long-term monitoring efforts (e.g., receiving water monitoring by wastewater or stormwater dischargers, post-remediation monitoring of clean up sites) can supplement the information from PSAMP and provide information more directly relevant to specific toxic control programs or projects

.

A number of scientists conduct studies of the effects of contamination on Puget Sound organisms. Scientists at the Northwest Fisheries Science Center study effects on marine fish, salmonids, and marine mammals. Scientists at USGS and USFWS study toxic contaminant exposure to and effects on river otters and birds, including osprey. Scientists from the Department of Fisheries and Oceans, the Canadian Wildlife Service and other parts of Canada’s federal government study toxic contaminant exposure to and effects on marine mammals and birds.

DOH scientists evaluate toxic contaminant information to assess risks from contaminated sites and from consumption of Puget Sound seafood.

Management of scientific data is not coordinated across projects or agencies. Data sharing is facilitated by efforts to develop web portals (e.g., Washington State's Natural Resource Data Portal) and a Puget Sound GIS consortium.

Results of scientific studies are presented in the scientific literature, agency technical reports, and numerous conferences and symposia (including regional, national and international meetings of science societies such as the Society of Environmental Toxicology and Chemistry and the Estuarine Research Federation). PSAT and Environment Canada lead a broad group of co-sponsors in convening a biennial Puget Sound Georgia Basin Research Conference where study results are shared, interpreted, and discussed.

4.7 Evaluation of how strategies address the pathways by which toxics are introduced to Puget Sound

Figure 3 (situation map) illustrates how the efforts discussed above are aligned to leverage assets, address threats, and achieve goals for toxics controls in the region. Some of the strategies and programs introduced above address multiple types of toxics release and others are focused on specific problems or sectors.

Table 3 summarizes the key responsibilities of government agencies to address the contaminant sources identified in Table 2. Figure 3, Table 3, and the discussion in section 4.1 through 4.6 above illustrate the key role of Ecology in toxics control and the significant contributions from EPA, WSDA, DNR, WSDOT, DOH, the U.S. Coast Guard, ACOE, Washington SeaGrant program, and State Parks.

5. Recommendations to Improve Toxics Control

The programs and activities introduced in Section 4 provide toxics controls that have been effective in many respects (e.g., concentrations of many contaminants are declining or holding steady over time, many types of toxics problems are confined to urban and/or industrial bays and are not widespread throughout the Sound). Nonetheless, Sections 2 above and the 2004 State of the Sound report[35] indicate that toxic contamination continues to be a concern for Puget Sound, especially harm from bioaccumulative contaminants to top predators (including humans), continuing harm to organisms resident in urban bays, and potential harm from new and minimally regulated chemicals.

In this section we briefly describe key needs to address gaps and/or uncertainties in the control of toxics that might harm or threaten to Puget Sound. Our analysis of these needs assumes that the programs introduced above will continue and can be adapted to improve their effectiveness. The recommendations presented in this section are based on our review of gaps and uncertainties related to

- Contaminants of concern in Puget Sound and chemicals on the Washington State PBT list that have not yet been evaluated in Puget Sound
- Sources and pathways of toxics delivery and distribution;
- Specific harms and threats observed from toxics in Puget Sound; and
- Strategies and actions to reduce input of toxic chemicals to Puget Sound.

Each section below includes a brief statement of an observation that suggested a need or a specific recommendation. Unless otherwise noted, these observations are based on evidence presented more fully in prior sections. Recommendations are presented in three categories: policy changes, new or adjusted programs or activities, efforts to fill information needs.

5.1 Recommended policy changes

Make producers responsible for ensuring the safety of chemicals used in commerce

Observations. Current federal chemical review practices (authorized under the Toxic Substances Control Act (TSCA)) do not adequately assess chemicals' risks before they enter commerce and models used to predict chemicals' properties and toxicity are not always accurate.[36]

Ecology's toxics reduction initiative and the NGO toxics free legacy coalition envision and work toward fundamental shifts in the burden of responsibility chemical use and management.

Recommendations. The Puget Sound Partnership should address this policy need in its effort to describe what is needed to achieve a healthy Puget Sound by 2020.

PSAT should broaden the scope of its toxic control efforts to include this type of shift in attitude and behavior in strategies and results in the 2007-09 Puget Sound conservation and recovery plan.

Governments should reform chemical policies to require that industry prove the safety of chemicals used in commerce (apply to chemicals in current use and to new chemicals before they are introduced into commerce).

Governments should reform policies to require producers, rather than consumers, to manage the full life cycle (cradle-to-grave) of their products and any toxic contaminants they might contain.

Improve product labels so consumers can make informed decisions about the potential for toxic exposures and releases

Observation. People have limited information about chemicals used in commerce and their potential risks and, therefore, have limited ability to participate in the chemical review process and to choose the safest and least toxic alternatives

Recommendation. Governments and/or industry associations should improve product labeling and product certifications to provide useful information about the chemicals present in consumer products.

Use economic incentives and disincentives to improve consideration of toxic controls in individual and business decisions

Observation. Harms and threats from toxic contamination are commonly quite distant in space or time from the cause of the harm or threat. This means that the relative merits of toxics controls are not easily factored into individual and business decisions.

Recommendations. Governments should develop incentives to encourage adoption of Puget Sound friendly behaviors – such as HOV commuting, pesticide-free yard care, water conservation, gray water retrofits.

Governments should develop financial incentives to encourage businesses to adopt low-toxics practices and/or financial disincentives (e.g., by taxing "bads" not goods and imposing significant penalties) to discourage poor practices.

Washington State should require that fees for permits to discharge wastewater or stormwater cover the full cost of developing and ensuring compliance with permits and a fair proportion of the social and environmental costs of harm resulting from permitted discharges.

Governments and private decisions that might affect the release of contaminants to the Puget Sound environment should explicitly consider the geographic distribution of toxics releases and the potential for exposures and harm to vulnerable or under-represented communities. The goal of would be to ensure that everyone enjoys the same degree of protection from toxic contamination and has equal access to the decision making process.

Update water quality standards

Observation. Some contaminants of concern in Puget Sound are not well addressed in the State's water quality standards (e.g., criteria may not be protective of sensitive life stages or species, numeric criteria are not in place for all contaminants) and existing standards and policies may not be protective of top-level predators.

Recommendations. Ecology should update water quality standards to address all Puget Sound contaminants of concern and most sensitive endpoints (e.g., hormone disruption in predators). Ecology should review and, as necessary, revise mixing zone policy to ensure that it protects against harm of toxics accumulated by high-level predators.

5.2 New and adapted programs and actions

Ensuring success in clean up of urban bays

Observations. The sediment cleanup at Eagle Harbor has been shown to effectively reduce the incidence of liver disease in local flat fish populations (e.g., see discussion in 2002 Puget Sound Update). In other Puget Sound locations, we do not yet have evidence that urban bay clean ups and pollution controls have reduced harm to flat fish.

PSAT's strategies and results for 2005-07 do not explicitly encompass coordinated clean up and source control at the scale of an urban bay to address the location-specific suite of harms and threats occurring at this scale.

Recommendations. Governments and responsible parties should monitor clean ups and governments should review monitoring results to evaluate the effectiveness of clean up on the scale of an impaired urban bay. This monitoring should be coordinated with characterization and evaluation of ongoing releases, especially from highly urbanized lands.

PSAT should develop strategies and results (i.e., for 2007-09) to encourage and facilitate coordinated clean up and source control at the scale of an urban bay.

Clean up work by Ecology, EPA, and responsible parties should be accelerated by continued infusion of public clean up funds to eliminate the contribution of historic contamination to ongoing problems in urban bays and in top-level predators.

Improving efforts to phase out of persistent, bioaccumulative toxic (PBT) chemicals

Observations. Ecology and DOH's PBT strategy offers an opportunity to reduce releases of toxics to Puget Sound via chemical-specific plans of action. Many of the chemicals of concern for toxic effects in Puget Sound and will (eventually) be subject to chemical action plans (CAPs) under this strategy.[37] CAPs are time and resource intensive to produce. Last biennium, only one plan (mercury) was completed and one was initiated (PBDE). There are 21 chemicals and 9 chemical categories targeted for plan development. At the current pace it would take several decades to develop and implement all of the plans.

Manufacturers agreed to cease production of both penta- and octa-DBE by the end of 2004, but production and use of deca-DBE continue. Deca-BDE accounted for 80 percent of the overall PBDE use in the United States prior to the voluntary phase outs.[38] Although deca-BDE is considered less toxic than both octa- and penta-DBE, it can degrade into more bioaccumulative and potentially toxic compounds.

Recommendations. PSAT should evaluate whether the phase out of PBTs via CAPs will achieve controls in a timely and effective manner, whether additional resources should be applied to development of CAPs and/or the balance needed between this and other approaches.

Governments and industry should continue investigating alternatives to deca-BDE and promote effective and safe alternatives for industrial use.

Reducing toxics discharged from sewage treatment plants

Observations. Some types of toxic harm in Puget Sound may be from contaminants delivered via sewage treatment plant discharges (e.g., reproductive impacts in urban flat fish, harms from pharmaceuticals and personal care products). A growing human population suggests that this source of harm could grow in the future if controls are not improved and that supplies of freshwater will be increasingly valuable in coming years.

Recommendations. The Puget Sound Partnership should adopt a goal of eliminating routine discharge of sewage treatment plant effluent to marine waters by 2020.

Ecology should define AKART for domestic sewage as treatment producing water suitable for re-use and should work with DOH and water suppliers to facilitate the highest and best use of the treated effluent.

Governments and utilities should maintain and accelerate trends toward increased reclamation and reuse of treated effluent from sewage treatment plants through facilities planning and the technical and financial assistance.

Ecology and wastewater utilities should identify toxics that are inadequately removed by sewage treatment plants and develop voluntary programs, including product labeling, as well as enhanced treatment methods to minimize their discharge to marine waters.

Reducing toxics discharged through industrial facility outfalls

Observations. Some types of toxic harm in Puget Sound may be from contaminants delivered via discharge of industrial process wastewater (e.g., PBDEs, phthalates, PAHs). Many Puget Sound industrial facilities have developed and are implementing pollution prevention plans. Ecology provides engineering and technical assistance to help facilities remove toxic chemicals from their processes, products and wastes.

Recommendations. As permits for industrial outfalls are renewed, Ecology and permit applicants should describe a level of treatment, including keeping toxics out of the waste stream, which would meet water quality standards at the end of the pipe. The reasonableness of this level of treatment should then be considered for the permit.

Ecology and EPA should partner with industry associations and/or individual facilities to develop and share information about process changes that save money, water and energy and reduce wastes. Sources of public funding for government contributions to this work should be developed.

For industries that have large water needs, Ecology, water suppliers and the industries should consider treatment allowing on-site water reuse and/or reclaimed water for off-site uses.

Government agencies and industry associations should broaden and raise the visibility of business certification programs (e.g., EnviroStars) as a means of helping consumers direct their purchasing and to document and promote viable and responsible business models in a number of sectors of commerce.

Governments should provide incentives to further facilitate and accelerate reductions in the use and generation of toxic chemicals consistent with pollution prevention plans.

Governments, NGOs, industry associations, and individual businesses should publicize stories of sustainable behaviors enhancing business viability.

Addressing deposition of air pollutants

Observation. PAHs are a contaminant of concern in Puget Sound and a large component of diesel soot. Atmospheric deposition of diesel soot to Puget Sound may be a significant contributor to PAH loadings to Puget Sound.

Recommendation. Clean air agencies and Ecology should expand their diesel soot control efforts to facilitate the retrofit of diesel engines in additional vehicle fleets and other sources of diesel emissions.

Continuing to improve spill prevention and response

Observation. A large oil spill that reached Puget Sound would compound the problems from ongoing toxic harm and would further threaten the viability of populations of birds, mammals, and fish.

Recommendation. Industry and government agency should continue improving their efforts to prevent, prepare for, and respond to spills by fully implementing the latest changes in laws and regulations relating to oil spills and developing additional improvements through the Oil Spill Advisory Council.

Addressing contributions of toxic contaminants from stormwater

Observation. Toxic contamination discharged via stormwater outfalls causes harm in streams and may contribute to PAH and pesticide contamination in Puget Sound's urban bays.

Recommendations. Local jurisdictions and WSDOT should characterize their discharges to urban streams and bays, collaborate with others to assess the potential contribution of stormwater to observed types of toxic harm, and retrofit stormwater management systems in priority areas to reduce the harm from toxics in stormwater.

Local jurisdictions with combined sewer systems should eliminate discharges of untreated combined sewage by improving treatment capacity and applying Low Impact Development measures to reduce the wet weather runoff.

Supporting species recovery

Observations. Recovery of species at risk (e.g., Chinook, orcas, and possibly marine birds such as scoters) will likely depend on toxics reductions to ensure the availability of a sufficient and clean food supply that does not impair reproduction, development, migration, and immune function.

The July 2005 draft Puget Sound Salmon Recovery Plan includes a broad recommendation to "implement strategies that prevent toxic chemicals, including those borne in stormwater, from entering Puget Sound and restore contaminated areas where benefits to salmon are expected" (Strategy D3 in Chapter 6). This plan further suggests that toxic reductions needed to support salmon population viability should be assessed and appropriate targets and actions should be included in sub-basin-specific clean up plans.

NOAA Fisheries' October 2005 draft Conservation Plan for Southern Resident Killer Whales includes a suite of toxics-related conservation measures. Many of these measures call for efforts to minimize inputs and releases, contamination, and risks.

<u>Recommendations</u>. Government agencies and other entities leading species recovery efforts should facilitate direct interactions between species recovery work and toxics control work to provide opportunities to focus toxics control to specific measures necessary for species recovery.

Governments (tribal, state, and federal) should coordinate management of fisheries for forage fish, salmon hatcheries, and salmon carcass disposal to address concerns about toxic harm to fish and predators on fish.

Education

<u>Observation</u>. Toxics problems arise from numerous sources, many of which can be controlled or influenced by individuals' decisions.

<u>Recommendations</u>. Governments and NGOs should collaborate to educate people about scientific findings, types of harm arising from various chemicals and sources, and practices that can be adopted and promoted to reduce toxic contamination of Puget Sound. Current efforts fall short of what is needed due to gaps in scientific information, uncertainty about messages and approaches that would best motivate behavior changes, and poor coordination of education efforts.

Retailers, government agencies, and NGOs should develop and use point of purchase information to direct consumers to less toxic approaches (e.g., as in integrated pest management).

Outreach to marinas and boaters to prevent small spills of fuel should be continued to reduce numbers of spills and harm from spills.

DOH and local health jurisdictions should continue to develop and provide consumers with advice about the role of Puget Sound seafood in a healthy diet to help reduce toxic exposures and to communicate about the problem of toxics in Puget Sound.

5.3 Efforts to fill information needs

Improving understanding about sources and pathways of toxics introduction and distribution

<u>Observations</u>. Overall and basin-specific loadings to Puget Sound have not been characterized for any of the chemicals of concern addressed in this paper. Estimates seem possible for many of the chemicals that have been subject to environmental study over the past decades.

Pathways by which humans and the Puget Sound ecosystem are exposed to PBDEs are poorly understood. Suspected pathways of exposure include releases from manufacturing or processing of the chemicals into products like plastics or textiles, aging and wear of consumer products, and direct exposure to humans during use (e.g., from furniture).

A study of trends in contaminant concentrations in the surface sediments of Puget Sound indicates that concentrations of most contaminants have not increased in recent years but that some PAHs are increasing in some locations.

Recommendations. Government or academic scientists should estimate loadings of contaminants of concern to various basins and support investigations of the pathways of contaminant distribution and accumulation to help inform the types and qualities of controls that should be instituted to confidently and efficiently decrease toxic harm in Puget Sound.

Government or academic scientists should develop information about the relative contributions from various sources of PAHs to the Puget Sound marine environment to support additional efforts to control PAH releases to Puget Sound.

Government and academic scientists should investigate the importance and sources of toxics deposited from the air to Puget Sound and its tributary watersheds; governments should evaluate these results and take appropriate actions to control key contributors to atmospheric deposition of toxics.

Governments and dischargers should coordinate monitoring to provide ongoing answers to questions about loadings of toxic chemicals and harms from discharges. Ecology and wastewater utilities should develop and present information about the actual and permissible loadings of key constituents from sewage treatment plants and the trends in these loadings. This would help direct financial and technical assistance to sewage treatment improvements at the facilities or in regions posing the greatest threats to Puget Sound.

Reducing hormone disruption in Puget Sound organisms

Observations. Hormone disruption is occurring in Puget Sound organisms and pharmaceuticals and chemicals from personal care products that may disrupt endocrine function are entering the marine environment.

Recommendations. Scientists should continue or enhance hormone disruption studies to identify causes of hormone disruption and their sources.

Improved coordination of information about toxics in the Puget Sound ecosystem

Observations. Toxic harms and toxic chemical sources are diverse; this complex situation raises the importance of science advice to managers. Current science coordination and science-management connections fall short of what is needed due to limited resources and poor coordination across studies, programs, and agencies.

Recommendations. Scientists from government and elsewhere should collaborate in an integrated, comprehensive program of scientific investigation to characterize conditions and stressors, test hypotheses relevant to toxics harm and control (e.g., exposure to chemical X disrupts hormone function in flat fish, concentrations of chemical Y are constant over time), organize hypotheses into simulation models, and develop and present science-based advice for managers. .

Ecology and other agencies should conduct additional sediment surveys and use available sediment data to identify additional contaminated sediment sites.

Scientists should advise orca recovery efforts by conducting studies of and developing advice about the degree of reductions needed to support orca population recovery.

Table 1. Toxic effects associated with contaminants of concern in Puget Sound. These are potential effects – not necessarily hypothesized to occur in Puget Sound.

Toxic effects of contaminant	Arsenic	Cadmium	Copper	Lead	Mercury	Tributyl tin	PCBs (polychlorinated biphenyls)	PAHs (polycyclic aromatic hydrocarbons)	Organochlorin pesticides	Organophosphorus and carbamate pesticides	Synthetic pyrethroid pesticides	Dioxins and furans	Phthalate esters	PBDEs (polybrominated diphenyl ethers)	Other components of pharmaceuticals and personal care products
Reduced survival of invertebrates	X	X			X	X	X	X	X						
Malformations of marine invertebrates	X					X									
Reproduction effects on invertebrates		X		X		X	X	X	X	X					
Impaired growth and development of invertebrates		X			X	X	X			X					
Paralysis of invertebrates											X				
Altered behavior in invertebrates					X	X		X	X	X					
Reduced survival of fish		X		X			X		X	X		X			
Impaired growth of fish	X	X		X		X	X			X			X		
Gill hemmoraging or other damage in fish	X	X	X									X			
Necrosis or lesions of liver in fish	X							X							
Brain lesions in fish					X										
Tumors in fish												X			
Reproductive effects in fish		X		X		X	X	X							X
Immune impairment in fish								X							
Neurological effects in fish				X							X				
Physiological alteration in fish		X		X	X	X	X	X	X			X			X
Teratogenic/developmental effects in fish		X		X											
Emaciation of fish					X										
Cataracts in fish					X										
Developmental abnormalities in fish						X						X			
Altered behavior in fish					X	X	X		X						X
Fin erosion								X				X			
Death of birds (from acute poisoning)	X			X											
Impaired growth of birds		X	X		X				X			X			
Reproductive effects in birds		X	X	X	X	X	X		X			X			
Developmental effects in birds			X		X										
Teratogenic effects in birds							X								
Physiological effects in birds							X			X					
Physical deformities in birds							X					X			
Anemia in birds		X													
Altered behavior in birds					X				X	X					
Liver abnormalities in birds								X							
Death of mammals			X				X					X			
Impaired growth of mammals	X				X							X		X	
Immune impairment in mammals	X		X			X	X					X			
Teratogenic/developmental effects in mammals		X			X				X			X		X	X
Liver and/or kidney damage in mammals			X				X					X		X	
Reproductive effects in mammals			X		X	X	X		X					X	X
Cancer in mammals							X	X	X					X	X
Altered behavior in mammals					X					X				X	
Neurological effects in mammals					X	X			X	X				X	
Physiological effects in mammals					X					X		X			
Bone structure effects in mammals						X								X	
Anorexia in mammals							X								
Gastric ulcers in mammals							X								
Skin lesions in humans	X											X			
Cancer in humans	X	X		X			X	X				X			X
Reproductive effects in humans	X											X			X
Decreased bone density in humans		X													
Kidney &/or liver dysfunction in humans		X							X			X			
Gastrointestinal effects in humans			X							X	X				
Neurological effects in humans				X	X	X	X		X	X	X	X			X
Immune impairment in humans									X			X			X
Cardiovascular & respiratory effects in humans												X			
Metabolism effects in humans (e.g., diabetes)												X			
Cholinesterase inhibition (nervous system activity)										X					
Endocrine disruptor?		Y		Y	Y	Y	Y					Y	Y	Y	Y
Bioaccumulates?	Y	Y	?	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	?
Biomagnifies in the food web?	N	N	N	N	Y	N	Y	N	?	N	N	Y	N	Y	?

Source: Toxicity characterizations presented in Sections 2.1 and 2.2 of "Status, Trends and Effects of Toxic Contaminants in the Puget Sound Environment" (EVS Environmental Consultants. 2003) and additional information reviewed by PSAT staff, including Ecology's January 2006 PBDE Action Plan, and Colburn et al., "Our Stolen Future" (PLUME, 1996).

Table 2: Human-associated sources of contaminants of concern for Puget Sound

Source of contaminant in Puget Sound environment		Arsenic	Cadmium	Copper	Lead	Mercury	Tributyl tin	PCBs (polychlorinated biphenyls)	PAHs (polycyclic aromatic hydrocarbons)	Pesticides	Dioxins and furans	Phthalate esters	PBDEs (polybrominated diphenyl ethers)	Other components of pharmaceutical and personal care products
Combustion	Fossil fuel combustion	X	X		X	X			X		X			
	Use of gasoline additives				X									
	Wood burning										X			
	Cigarette smoke										X			
Manufacturing	Metal mining, processing & reprocessing	X				X								
	Base metal smelting & refining		X	X										
	Metal plating		X	X										
	Manufacture of alloys				X									
	Heavy metal soaps				X									
	Manufacture of ammunition				X									
	Aluminum smelters								X					
	Metallurgical & coke production								X					
	Petroleum refining				X				X					
	Chloralkali plants					X								
	Bleaching processes in pulp & paper mills										X			
	Manufacture of plastics		X									X		
	Stabilizers in PVC resin						X					X		
Pest management	Manufacture, application & improper disposal of pesticides	X		X				X		X	X			
	Wood preservatives, including creosote	X		X			X		X					
	Applications of lead arsenate	X			X									
	Antifouling paint on ship & boat hulls			X	X		X							
	Antifouling paint on bridges				X									
	Antifouling paint on docks, fish nets & buoys						X							
Petroleum handling	Tanks & piping				X				X					
	Spills of petroleum								X					
Product manufacture, use and/or disposal	Manufacture, disposal & weathering of pigments & paints		X	X	X		X	X	X					
	Manufacture & disposal of batteries		X		X									
	Vehicle use -- weathering of roadways & parking lots; wear of tires & brake pads		X	X					X					
	Vehicle maintenance &equipment repair				X				X					
	Improperly disposed dental amalgam material					X								
	Disposal of fluorescent lamps, thermometers, automobile light switches, & thermostats					X								
	Manufacture & use of textile disinfectants						X							X
	Manufacture, use, recycling & disposal of carbonless paper							X						
	Manufacture & use of dust control agents							X						
	Manufacture, use & disposal of inks							X						
	Manufacture, use & disposal of perfumes, skin care and other personal care products											X		X
	Manufacture, use & disposal of aerosols											X		
	Use & disposal of products with plasticizers							X				X		
	Leaking of cooling & insulating fluid in industrial transformers & capacitors							X						
	Leaking of hydraulic fluids							X						
	Leaking of heat transfer fluids							X						
	Manufacture, use & disposal of products with flame retardants												X	
Waste management	Municipal waste water discharges			X	X				X			X	X	X
	Municipal sewage sludge applications		X									X	X	X
	Solid waste disposal		X									X	X	X
	Municipal waste incineration										X			
	Incomplete incineration of other chlorinated organic chemicals										X			
	Residential burning of garbage										X			

Sources: Alford-Stevens 1986; Atkinson 1992; Eisler 1987a; Eisler 1988a; Environment Canada 1993a; Environment Canada 1994a,b; EXTOXNET 1996a; Garrett and Shrimpton 1997; IEMPOP 1995; Kociba and Schwetz 1982a,b; NOAA 1994; PTI 1991; and USEPA 1985 as cited in “Status, Trends and Effects of Toxic Contaminants in the Puget Sound Environment” (EVS Environmental Consultants. 2003. Prepared for the Puget Sound Action Team. EVS Project No. 02-1090-01. October 2003.) With some additions by PSAT staff.

Table 3: Management programs to affect human-associated sources of contaminants

Key:
R = regulation
R/E = regulation via ESA
$ = funding
P = permitting
I = implementation
A = assistance

Source of contaminant in Puget Sound environment		U.S. EPA	NOAA Fisheries	U.S. Fish & Wildlife	U.S. Army Corps of Engineers	Dept. of Ecology	Dept. of Natural Resources	Dept. of Health	Dept. of Agriculture	CTED	Dept. of Transportation	State Parks & Recreation	Dept. of Fish & Wildlife	Conservation & Districts	Tribes	Counties & local health jurisdictions	Cities	Local clean air agencies	Ports	UW Sea Grant Program & WSU Coop. Extension
Combustion	Fossil fuel combustion	*R$*				*R$*			*R*		*$*					*R*		*RP*	*$*	
	Past use of gasoline additives	*R*				*R$*		*R*	*R*											
	Wood burning	*R*				*R*	*RP*								*R*			*RP*		
	Cigarette smoke							*R*												
Manufacturing	Metal mining, processing & reprocessing	*R*	*R/E*	*R/E*		*RP*	*RP*													
	Base metal smelting & refining	*R*				*RP*														
	Metal plating	*R*				*RP*														
	Manufacture of alloys	*R*				*RP*														
	Heavy metal soaps	*R*				*RP*														
	Manufacture of ammunition	*R*				*RP*														
	Aluminum smelters	*RA*				*RPA*	*P*													
	Metallurgical & coke production	*R*																		
	Petroleum refining	*RA*				*RPA*	*P*													
	Chloralkali plants	*RA*				*RPA*	*P*													
	Bleaching processes in pulp & paper mills	*RA*				*RPA*	*P*													
	Manufacture of plastics	*R*				*RPA*														
	Stabilizers in PVC resin	*R*				*RPA*														
Pest management	Manufacture, application & improper disposal of pesticides	*R*	*R/E*	*R/E*		*R$*	*RPI*		*A*		*I*	*I*	*PI*	*A*					*I*	
	Wood preservatives, including creosote	*R*	*R/E*	*R/E*		*R*	*P*				*I*		*P*						*I*	
	Past applications of lead arsenate	*R*				*R*														
	Antifouling paint on ship & boat hulls	*R*	*R/E*			*R*							*P*						*I*	
	Antifouling paint on bridges	*R*	*R/E*			*R*					*I*		*P*							
	Antifouling paint on docks, fish nets & buoys	*R*	*R/E*			*R*														
Petroleum handling	Tanks & piping	*R*	*R/E*			*R*													*I*	
	Spills of petroleum	*R*	*R/E*			*R*							*R*						*I*	
Product manufacture, use and/or disposal	Manufacture, disposal & weathering of pigments & paints	*R*				*R*					*I*					*R*				
	Manufacture & disposal of batteries	*R*				*R*										*R*				
	Vehicle maintenance &equipment repair	*R*				*R*														
	Improperly disposed dental amalgam material	*R*				*R*		*R*												
	Disposal of fluorescent lamps, thermometers, automobile light switches, & thermostats	*R*				*R*		*R*								*R*				
	Manufacture & use of textile disinfectants	*R*				*R*														
	Manufacture, use, recycling & disposal of carbonless paper	*R*				*R*														
	Manufacture & use of dust control agents	*R*				*R*												*R*		
	Manufacture, use & disposal of inks	*R*				*R*										*R*				
	Manufacture, use & disposal of perfumes, skin care and other personal care products	*R*				*R*										*R*				
	Manufacture, use & disposal of aerosols	*R*				*R*										*R*				
	Use & disposal of products with plasticizers	*R*				*R*														
	Leaking of cooling & insulating fluid in industrial transformers & capacitors	*R*				*R*										*R*				
	Leaking of hydraulic fluids	*R*				*R*														
	Leaking of heat transfer fluids	*R*				*R*														
	Manufacture, use & disposal of products with flame retardants	*RA*				*RA*														
Waste management	Municipal waste water discharges	*PR$*	*R/E*	*R/E*		*PR$*				*$*						*I$*	*I$*			
	Municipal sewage sludge applications	*R*	*R/E*	*R/E*		*PR$*				*$*						*I$*	*I$*			
	Solid waste disposal	*R*				*PR$*										*I$*	*I$*			
	Municipal waste incineration	*R*				*R*												*IR*		
	Incomplete incineration of other chlorinated organic chemicals	*R*				*R*														
	Residential burning of garbage	*R*				*R*										*R*		*R*		

Figure 1: Mechanisms of Toxics Delivery to Puget Sound

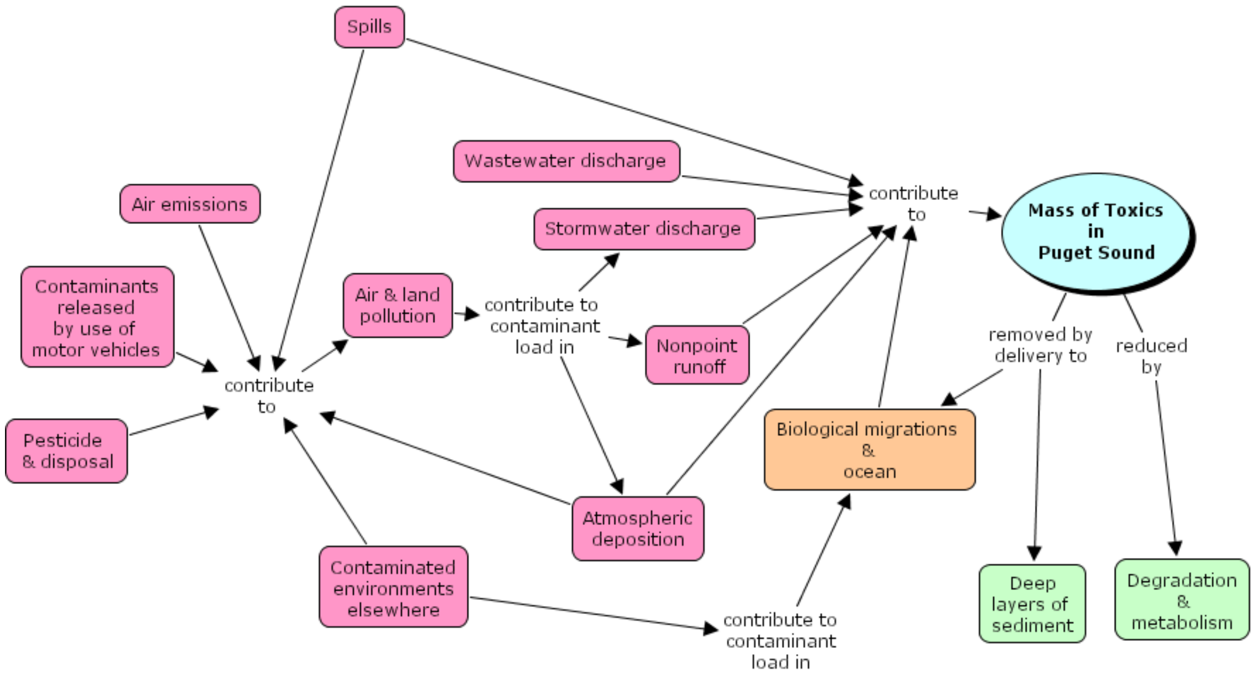


Figure 2: Contaminants accumulate in the marine food web, such as this food web for the open waters of northern Puget Sound[41]

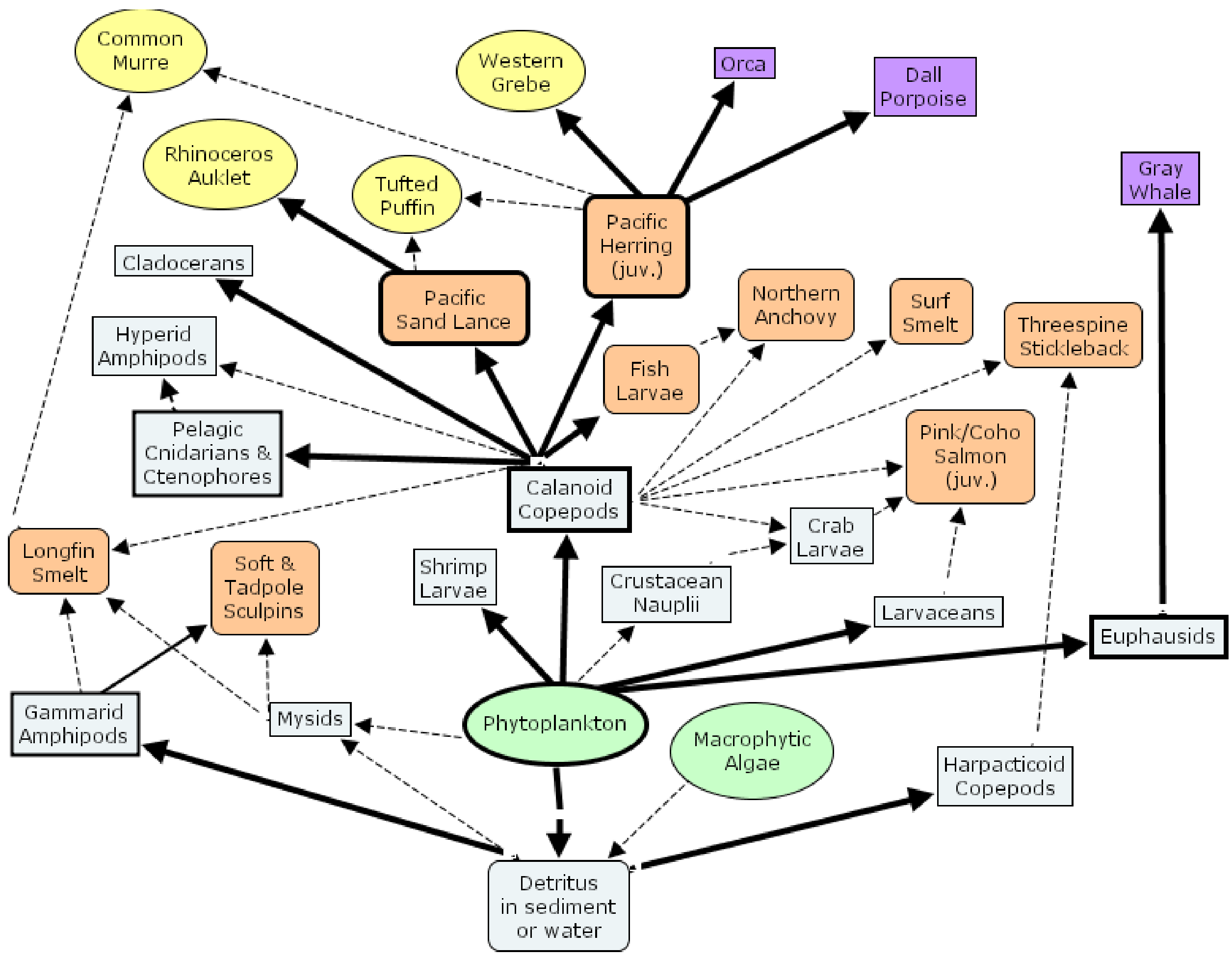
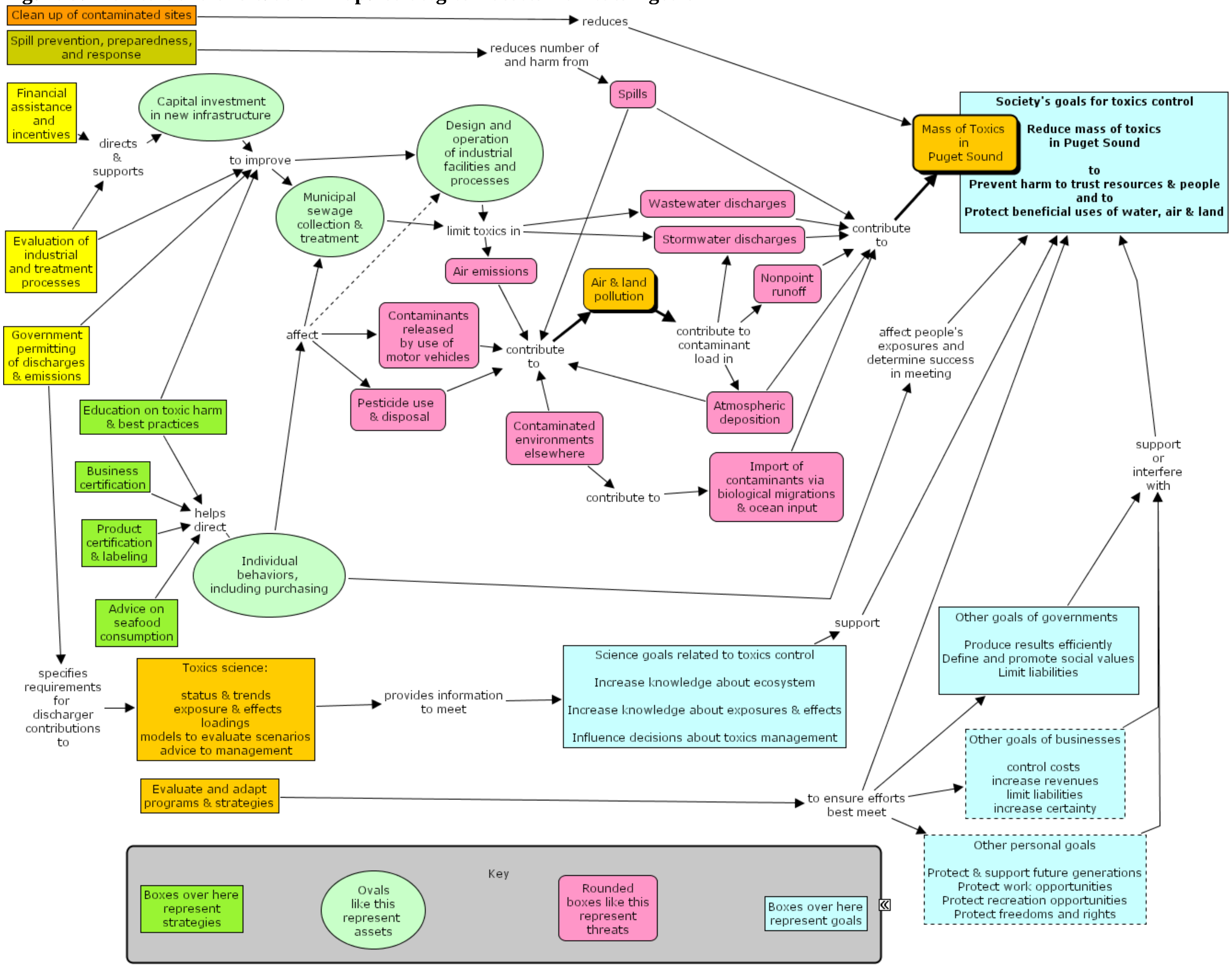


Figure 3: Toxics Control Situation Map: strategies – assets – threats – goals



[1] For example, the following reports discuss the threats of toxic chemicals to Puget Sound and the need for management activities:

Grant, S.C.H. and P.S. Ross. 2002. Southern Resident Killer Whales at Risk: Toxic Chemicals in the British Columbia and Washington Environment. Can Tech.Rep.Fish.Aquat.Sci. 2412:xii+111 p.

Johnson, L.L., M.S. Myers, D. Goyette, R.F. Addison. 1994. Toxic Chemicals and Fish Health in Puget Sound and the Strait of Georgia. pp. 304-329 In Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait. Eds. Wilson, E.C.H, R.J. Beamish, F. Aitkens, J.Bell. Canadian Technical Report of Fisheries and Aquaitic Sciences 1948. April 1994.

Puget Sound Action Team. 2005. State of the Sound 2004. Publication No. PSAT 05-01. January 2005.

Puget Sound Water Quality Authority. 1988. State of the Sound 1988 Report.

Quinlan, E.A., P.M. Chapman, R.N. Dexter, D.E. Konasewich, C.C. Ebbesmeyer, G.A. Erickson, B.R. Kowalski, T.A. Silver. 1986. Toxic Chemicals and Biological Effects in Puget Sound: Status and Scenarios for the Future. Draft NOAA Technical Memorandum.

Schmidt, M. and P. Johnson. 2001. Toxics in the Puget Sound Food Web. People for Puget Sound. December 2001.

[2] EVS Environmental Consultants. 2003. Status, Trends and Effects of Toxic Contaminants in the Puget Sound Environment. Prepared for the Puget Sound Action Team. EVS Project No. 02-1090-01. October 2003.

[3] EVS's recent review of toxics in Puget Sound (cited above) describes the occurrence of contaminants in various parts of the Puget Sound marine ecosystem:

- Sediment – includes widespread contamination by arsenic, copper, lead, mercury, and PAHs are widespread; much contamination by PCBs, phthalate esters, furans, and DDT; and limited contamination by cadmium and tributyl tin.
- Invertebrates, including shellfish – arsenic, PCBs, and DDT are present in shellfish tissue throughout Puget Sound.
- Salmon and marine fish – English sole are contaminated by PAHs (evidence is through metabolites in bile), arsenic, lead, and organochlorine contaminants such as PCBs; Puget Sound Chinook salmon are more contaminated with PCBs than Chinook from elsewhere on the West Coast.
- Birds and mammals -- PCB concentrations in eggs of bald eagles from Hood Canal exceed effects thresholds; overwintering surf scoters near Commencement Bay accumulate contaminants; harbor seals and orcas in Puget Sound accumulate organochlorine contaminants.

[4] Ecology. 2005. Sediment Cleanup Status Report. Toxics Cleanup Program. Ecology Publication No. 05-09-092. June 2005.

[5] Johnson, L., D. Lomax, O.P. Olson, J. West, and S. O'Neill. 2005. Xenoestrogen exposure and altered reproductive timing in Puget Sound English sole. In Proceedings of the 2005 Puget Sound/Georgia Basin Research Conference. Puget Sound Action Team.

[6] Schmidt, M. and P. Johnson. 2001 (cited above)

[7] Results of a U.S. Fish and Wildlife Service study reported in 2000 Puget Sound Update. (Page 66 in PSAT. 2000. 2000 Puget Sound Update: Seventh Report of the Puget Sound Ambient Monitoring Program Olympia, Washington.)

[8] Elliott, J.E., L.K. Wilson, R. Norstrom, and M.L. Harris. 2003. Chlorinated Contaminant Trends in Indicator Species, Great Blue Herons and Double-crested Cormorants, in the Strait of Georgia, 1973-2000. In Proceedings of the 2003 Georgia Basin/Puget Sound Research Conference. Puget Sound Action Team.

[9] Puget Sound Action Team. 2005. State of the Sound 2004. Puget Sound Action Team, Office of the Governor. Pub. No. PSAT 05-01. January 2005.

[10] Puget Sound Action Team. 2005. (cited above).

[11] National Research Council. 2003. Oil in the Sea III: Inputs, Fates, and Effects. The National Academies Press. Washington DC. p. 120.

[12] National Research Council. 2003. (cited above).

[13] National Research Council. 2003 (cited above).

[14] Yender, R. 2006. NOAA Fisheries presentation: Overview of Environmental Impacts, Shoreline Assessment and Cleanup. Presented at the Northwest Oil Spill Awareness Course. January 2006.

[15] National Research Council. 2003. (cited above).

[16] Yender, R. 2006. (cited above).

[17] Personal communication via Powerpoint presentation by Lyndal Johnson, Northwest Fisheries Science Center.

[18] Hardy, J. 2005. Evaluation of Polychlorinated Biphenyls (PCBs), Mercury, and DDT in Rockfish, English sole, Chinook Salmon and Coho Salmon from Puget Sound, Washington. In Proceedings of the 2005 Puget Sound Georgia Basin Research Conference. Puget Sound Action Team

[19] Penta-BDE is a mixure of five congeners (BDE-47, BDE-99, BDE-100, BDE-153 and BDE-154. Octa-BDE contains a number of hexa- to nona- brominated congeners (i.e., six to nine bromine atoms per molecule). Deca-BDE is predominantly composed of the fully brominated congener (BDE-209).

[20] See for example, Northwest Environment Watch's report on PBDE's in breast milk from Pacific Northwest, including Seattle, mothers (http://www.northwestwatch.org/toxics/PBDEs_in_NW.pdf), Toxic Nation's report on contaminants in Gulf Islands' resident Robert Batemen (http://www.environmentaldefence.ca/toxicnation/report/volRobert.htm), and abstracts of the papers presented at Session B3 of the 2005 Puget Sound Georgia Basin Research Conference: Flame Retardants: Science and Policy Perspectives (http://www.psat.wa.gov/Publications/05_proceedings/oral_presentations.html#b3)

[21] Peele, C. 2004. Washington State Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Interim Plan. Washington State Department of Ecology report no. 04-03-056.

[22] US Department of Health and Human Services Centers for Disease Control and Prevention. 2005. Third National Report on Human Exposure to Environmental Chemicals. NCEH Pub. No. 05-0570. July 2005. pp. 253-282.

[23] Windward Environmental LLC. 2005. Lower Duwamish Waterway Remedial Investigation Data Report: Fish and Crab Tissue Collection and Chemical Analyses Final. Prepared for the U.S. Environmental Protection Agency and the Washington State Department of Ecology. July 17, 2005.

[24] Grant, S.C.H and P.S. Ross. 2002. (cited above)

[25] National Center for Policy Analysis retrieved from http://www.ncpa.org/iss/hea/2003/pd091603d.html on 11/29/05.

[26] Reynolds, K. 2003. Water Conditioning and Purification Magazine. Vol. 45, No. 6. Retrieved 11/29/05 from http://www.wcp.net/column.cfm?T=T&ID=2199.

[27] Bound, J. and N. Voulvoulis. 2005. Household Disposal of Pharmaceuticals as a Pathways for Aquatic Contamination in the United Kingdom. Environmental Health Perspectives. Vol. 113. No. 12. pp. 1705-1711.

[28] In 2002, the U.S. Geological Survey conducted a national reconnaissance for hormones, pharmaceuticals and other organic wastewater compounds in US Rivers and streams. They reported low levels of these compounds in four Puget Sound rivers. They found detergent metabolites, steroids, plasticizers and nonprescriptive drugs in the highest concentrations. The suite of prescribed drugs that the Geological Survey analyzed included bronchial dilators, antacids, analgesics, antianginal and cardiac stimulants, as well as antihypersensitive, antidepressant, cholesterol regulators and anti-diabetic drugs. (US Geological Survey. 2002. National Reconnaissance of Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in Streams of the US, 1999-2000. Retrieved from http://toxics.usgs.gov/regional/emc_surfacewater.html on 11/29/05)

In 2003 and 2004, King County scientists surveyed marine and fresh waters for sixteen potential endocrine disrupting chemicals including six natural and synthetic hormones. Eleven of the 16 chemicals were detected and the majority of the detections were in freshwaters. Streams appeared to have generally higher concentrations of bisphenol A, bis(2-ethylhexyl)phthalate, nonylphenol, 17b-estradiol, and ethynylestradiol than lakes. Marine waters had very few detections. Most detections in all waters were low relative to analytical detection limits. (Personal communication with Betsy Cooper, NPDES Administrator, Wastewater Treatment Division, King County on 12/22/05).

In 2004, Ecology screened for 24 compounds in City of Sequim wastewater. Ecology found very low levels of 16 compounds including anti-inflammatory compounds, caffeine, anti-epileptic drugs, ulcer drugs, analgesics, nicotine, bronchial dilators, antibacterial compounds and estrone (hormone component). (Department of Ecology. 2005. Results of a screening Analysis for Pharmaceuticals in Wastwater Treatment Plant Effluents, Wells, and Creeks in the Sequim-Dungeness Area. Department of Ecology Report No. 04-03-051. Retrieved from http://www.ecy.wa.gov/biblio/0403051.html on 11/29/05.)

[29] Cone, M. 2005. Sewage Altering Fish, Study Reports. Los Angeles Times. Note: this news article was a summary of a study by Daniel Schlenk, Professor of Aquatic Ecotoxicology and Environmental Toxicology at University of California Riverside. Schlenk presented the results of the study at the Society of Environmental Toxicology and Chemistry North America 26th annual meeting in Baltimore Maryland on November 2005.

[30] United State Government Accountability Office. 2005. Chemical Regulation Options Exist to Improve EPA's Ability to Assess Health Risks and Manage its Chemical Review Program. GAO report No. GAO-05-458. June 2005.

[31] EVS Environmental Consultants. 2003. (cited above)

[32] This list captures most of the specific parameters of concern for sediment clean ups in Puget Sound. Additional chemicals that are identified as targets of sediment clean ups include: benzoic acid, benzyl alcohol, hexachlorobutadiene, hydrocarbon and total petroleum hydrocarbon (TPH), methyl phenols, ordnance, phenol(s), silver, and sulfite. Toxicity in bioassays and wood debris are also listed a targets of sediment cleanup at some Puget Sound sites. Other sediment contaminants in Puget Sound include chlorinated benzenes and phenols, guaiacols, and resin acids.

[33] In the past decade, Ecology and EPA have initiated efforts to address the environmental and human health threats posed by persistent, bioaccumulative, and toxic (PBT) chemicals. Most, but not all, of the chemicals of concern due to known or suspected harm from toxic effects in the Puget Sound ecosystem are identified as PBT chemicals. Some non-PBT metals are of concern as sediment contaminants although they may not bioaccumulate and some non-PBT pesticides may have short-term effects in marine systems even though they are not especially persistent.

[34] The diagrams presented in Figures 1 through 3 were developed as extensions of the PSAMP conceptual model (Newton et al. 2000. Puget Sound Action Team) which describes the relationships between human activities, stressors, and ecosystem impacts. The next section picks up the final element of that conceptual model: management programs to control activities so that stresses are reduced.

[35] Puget Sound Action Team. 2005. State of the Sound 2004. Publication No. PSAT 05-01. January 2005.

[36] United State Government Accountability Office. 2005. Chemical Regulation Options Exist to Improve EPA's Ability to Assess Health Risks and Manage its Chemical Review Program. GAO Report No. GAO-05-458. June 2005. This report notes that there are currently 82,000 chemicals in the TSCA inventory but only 40,000 of these have been reviewed by EPA (since 1979).

[37] The following contaminants of concern for Puget Sound are not listed as PBT chemicals and may require some additional attention: arsenic, copper, tributyl tin, current use pesticides, pharmaceuticals, and chemicals of concern in personal care products.

[38] Peele, C. 2004. Washington State Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Interim Plan. Washington Department of Ecology and Washington Department of Health. Washington Department of Ecology Publication No. 04-03-056. December 31, 2004.

[39] The following contaminants of concern for Puget Sound are not listed as PBT chemicals and may require some additional attention: arsenic, copper, tributyl tin, current use pesticides, pharmaceuticals, and chemicals of concern in personal care products.

[40] Peele, C. 2004. Washington State Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan: Interim Plan. Washington Department of Ecology and Washington Department of Health. Washington Department of Ecology Publication No. 04-03-056. December 31, 2004.

[41] Adapted from Simensted C.A., B.S. Miller, C.F. Nyblade, K. Thornburgh, and L. J. Bledsoe. 1979. Food Web Relationships of Northern Puget Sound and the Strait of Juan de Fuca: A Synthesis of Available Knowledge. EPA-600/7-70-259.